



VERSION 1.0

User's Guide



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**ATTENTION! READ THIS MANUAL
COMPLETELY PRIOR TO USE**

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English Edition
Version 1.0

Important remarks concerning the manual

This manual makes use of the following icons to indicate especially important comments.



Indicates information about details which are important to prevent a risky situation.



Indicates a potentially hazardous situation which, if not avoided, could result in death or injury.

Nautilus Dive Planner User's Guide Version 1.0

By Joel D. Silverstein and R. Dan Nafe
1st Edition, March, September 2005

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The program is written and designed by R. Dan Nafe and Joel D. Silverstein.

NAUTILUS DIVE PLANNER runs under Microsoft Windows 3.1, 3.11, 95, 98, NT, ME, XP, Windows is a registered trademark of the Microsoft® Corporation. Mac OS 8.5, 9, X is a registered trademark of Apple Computer Inc., and Linux/X86 w/GTK. No representation is made to the complete compatibility of any hardware or software.

The names: NAUTILUS Dive Planner Software, Nautilus Dive Planner and Nautilus
are use interchangeably throughout this manual and all result in the same meaning.

website: <http://www.nautilusdiveplanner.com>

e-mail support@nautilusdiveplanner.com

discussion group: <http://groups.yahoo.com/group/nautilusdiveplanner/>

Special thanks to:

Hamilton Research Ltd. - R.W. Bill Hamilton, PhD & David Kenyon
National Oceanographic and Atmospheric Administration - David Dinsmore

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Notes

Nautilus Dive Planner Software



Warnings and Safety Considerations

Important Safety Considerations

- If you are not educated in the workings of decompression procedures please seek out training from a reputable internationally recognized training agency before using this product.
- Using pure Oxygen or Oxygen enriched gases, Trimix, Heliox or any gas mixture that contains an Oxygen content more or less than 21% (straight air) needs special safety measures and appropriate training. Please consider the general safety considerations of using breathing mixtures other than air.
- No decompression table, program, schedule or output can ever assure that you will not be subject to decompression sickness. Use of this software is at your own risk.
- If the diver uses the wrong value of the gas mixture he /she or the dive computer could calculate insufficient decompression time (EAD, END, PO2, PN2) or oxygen toxicity (MOD, CNS, OTU etc.). Both situations could result in death or serious injury.
- Avoid  situations which  are marked in this manual with CAUTION and STOP
- Do not use Nautilus Dive Planner for actual dives which you have not been trained for.



General Information

This user's guide is designed to help the **certified diver, nitrox diver, mixed gas diver, or rebreather diver to:** understand the need and application of planning dives that require decompression planning. This manual does NOT purport to be a replacement for certification courses in the subject area or will it provide information on how to conduct the operations of a single dive or series of dives. Users who utilize the values presented in NAUTILUS accept all risks of use.

This user's guide will provide information as to the operational use of the **NAUTILUS Dive Planner Software** program.

The **Nautilus Dive Planner Software** is for the trained and certified diver, and gas mixing technician. **Nautilus Dive Planner Software** requires that the user analyze and verify BOTH the oxygen and helium content of any gas that will be used prior to completing any dive that has been planned with the **Nautilus Dive Planner Software** program. A complete log should be maintained for all gas mixtures. It is the **USER'S SOLE RESPONSIBILITY** to properly record the gas percentages and label the cylinder being analyzed appropriately. Improper gas analysis and transferring that improper analysis to the **Nautilus Dive Planner Software** may produce decompression results that can cause injury, disability, or death.



ATTENTION This guide does not purport to be a complete study or presentation on dive planning, or decompression planning. Users should seek out other additional information for those areas of expertise.



WARNING: USING OXYGEN MIXTURES CONTAINING 16% or LESS OXYGEN CONTENT AT THE SURFACE CAN CAUSE INJURY OR DEATH FROM HYPOXIA



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Nautilus Dive Planner Product Overview

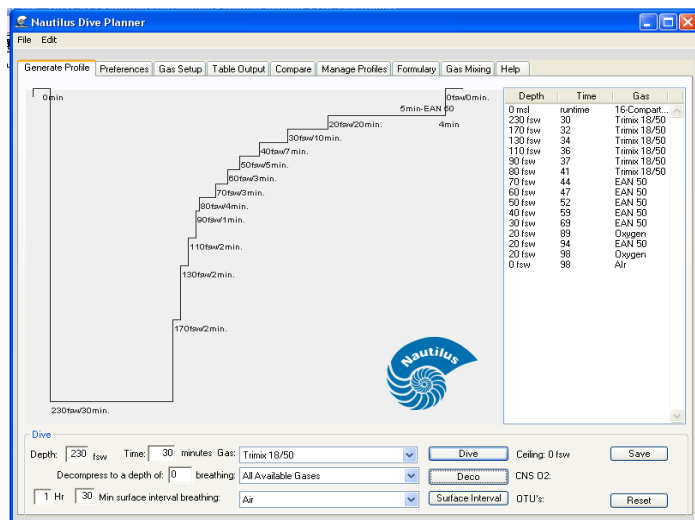
1.1 NAUTILUS DIVE PLANNER OVERVIEW

Welcome to **NAUTILUS Dive Planner Software**. NAUTILUS is the new generation of Technical Dive Planning Software and the most comprehensive dive planning tool developed during the last few years. We are now 15 years into desktop dive decompression software products yet most of the products on the market are limited in their ability to deliver a wide variety of features and functions. Many have been homegrown products that have gained cult-like loyalty by some users, but still lack the full features and variable controls desired by most of today's advanced and technical divers.

The introduction of **NAUTILUS Dive Planner Software** is a new approach to planning decompression dives and in the manner in which it delivers the myriad of information a diver needs to efficiently plan, compare, and analyze dives. It makes no difference to NAUTILUS if the diver is using one gas, three gases, or ten gases. It also makes no difference if the diver will dive on conventional open circuit scuba or closed circuit scuba, or a combination of both—NAUTILUS manages it all!

NAUTILUS is a control panel for the technical diver or instructor. The NAUTILUS control panel allows the user to make rapid selections of important components of the dive plan in an easy-to-understand manner. By utilizing "tabs" similar to that on a notebook the user can quickly navigate to the area they want to work in, make the selections, save that information and then plan the dive and create the table output.

NAUTILUS allows the user to select from not one but a variety of popular and proprietary decompression



algorithms. NAUTILUS allows the user to make adjustments to the outputs of those algorithms through the use of gas selections, avoiding stops at particular depths, selecting maximum PO₂ levels, choosing stop time or run-time, inserting micro-bubble minimization deep stops and much more!

This **Version of NAUTILUS DIVE PLANNER** introduces a wide range of new and exciting features that were previously unavailable to desktop decompression planning. With NAUTILUS users are able to make detailed plans and then perform a simulated dive based on that information. During the simulation NAUTILUS will track and inform the user of a wide variety of information to help you plan and execute an actual dive. NAUTILUS is not intended or designed for the novice SCUBA diver, but rather for the experienced diver or a diver who is enrolled in a qualified training course where NAUTILUS is being introduced.



1.2 NAUTILUS USER VERSIONS

Nautilus Dive Planner Software comes in six versions. Each is a complete full working version of NAUTILUS but is limited in the maximum operating depth. These depth levels correspond with popular technical diving certification levels. We do not limit the purchase of any of the versions except for one. The licensee of one version will be able to purchase upgrades to the next depth version.

Nautilus 70	Maximum Depth 70 fsw / 21 msw
Nautilus 140	Maximum Depth 140 fsw / 42 msw
Nautilus 225	Maximum Depth 225 fsw / 68 msw
Nautilus 330	Maximum Depth 330 fsw / 100 msw
Nautilus 660	Maximum Depth 660 fsw / 200 msw
Nautilus RE	Maximum Depth 1500 fsw / 455 msw

We anticipate that the most popular versions will be Nautilus 140, 225, and 330. The Nautilus RE (research) version is limited in availability to laboratories, universities, military, and commercial diving companies only.

Each version of Nautilus allows for complete decompression planning with either open circuit, closed circuit or a combination of those diving modes. Users can select from air, oxygen, nitrox, trimix, heliox, nitrox setpoint or heliox setpoint gas modes. Users can plan square, multilevel, or repetitive dive profiles with complete control and interchangeability of diving modes.

Nautilus Dive Planner is the only decompression planning software that incorporates the full functions of a true decompression planning tool with a choice of decompression algorithms and models.

1.3 NAUTILUS FUNCTION TABS

Nautilus Dive Planner Software uses tabs inside the program to allow for navigation to the individual function pages. They are arranged left to right in the order that the user will access them after the initial setup. Ultimately once the users “standard” preferences are set the tabs will not need to be accessed until the next time preferences need to be modified. This section will describe each TAB set. The next section will take you through each of them with screen shots.

1.31 GENERATE PROFILE:

Here is where the actual dive profile is entered and viewed in a simple graphical display. Square profile, multilevel profile, and repetitive dives are easily plotted here and the decompression profile is viewed.

Preferences:

This is the heart of Nautilus’ settings. Under this tab the user will select:

Units: Imperial or Metric

Table Type: Stop Time or Run Time method of display

Scuba Type: Open Circuit / Semi-Closed Circuit

SAC rate in cfm or lpm

Closed Circuit (Constant PO₂)

High Set Point (either heliox or nitrox)

Low Set Point (either heliox or nitrox)



Decompression / Bailout SAC rate

Air Breaks: No Air Breaks

Classic Air Breaks

Custom Air Breaks Rule

Decompression Models:

- Hamilton-Kenyon Model (DCAP) 11 compartment
- Buhlmann 16 compartment
- 4-Compartment Serial (DCIEM)
- 10 Compartment Neo-Haldanian
- 12-Compartment (Huggins-Nafe)
- Variable Permeability Model (VPM)
- US Navy
- Conservatism Slider Bar – 0-90

Deep Stops: No Deep Stops

Pyle Stops

Custom Rule Stops

Altitude: Starting Altitude

Post Dive Altitude

Deco Preferences:

Max PO2 on Deco .16 bar/atm - 2.0 bar/atm

Shallowest Deco Stop: 10-40 fsw (3-12 msw)

Avoid Stops at: 10, 20, 30, 40 fsw (3,6,9,12 msw)

Avoid Stop at custom depth

Deco Stops Intervals 10-30 fsw in 1 foot increments

Reset: This resets all changes to the Preference Screen to the base defaults.

Save: This saves the preferences set for use now and until it is reset.

1.3.2 GAS SETUP

The GAS SETUP screen is divided into two sections:

Available Breathing / Decompression / Travel Mixes section with 14 predefined gas mixtures including air plus the ability to create and save up to 13 more “custom mixes.”

Define Custom Mixes allows the user to create specific mixes that can then be added to the Available Mix portfolio.

A future feature will have the Gas Portfolio linked to the GAS MIXING tab for automatic entry to aid in creating the gas mix routine for actually mixing the gas.

1.3.3 TABLE OUTPUT

This Tab is where NAUTILUS displays the output of the Dive Profile and allows the user to View, Print, Export, and save the display of the dive. Users can choose from:

- Short Table
- Long Table
- Schedule Output with variable time and depth
- Export to Text File
- Export to HTML

1.3.4 COMPARE

This feature allows the user to compare, separate, and distinct profiles. This is an outstanding feature for looking at the time depth profiles, comparing OC to CCR, or for presentation and educational purposes.

Overlay Mode: - shows the dive profile graph on top of each other.

Two Window Mode: - shows the dive profile graphs stacked one above the other.

1.3.5 MANAGE PROFILES

Database listing of dive profiles stored in NAUTILUS allows the user to scroll through previously created profiles and to access the data, modify, and re-save if desired.

1.3.6 FORMULARY

Formulary is the fun screen that allows the user to access tools that will help them look at different gas mixes and identify certain facts about them including END, CNS, OTU, RMV, PO₂, MOD and much more.

1.3.7 GAS MIXING

Complete calculator for mixing gas either from empty or partially full cylinders.

Mixing modes include:

Nitrox using:

Oxygen and Air

Trimix using:

Helium and Air

Helium, Oxygen, and Air

Helium and Nitrox

Helium, Oxygen, and Nitrox

Heliox and Air

Heliox, Oxygen, and Nitrox

Air Top Ups of:

Nitrox or Trimix with the ability to add a specific gas so as to change the final composition of the mix.

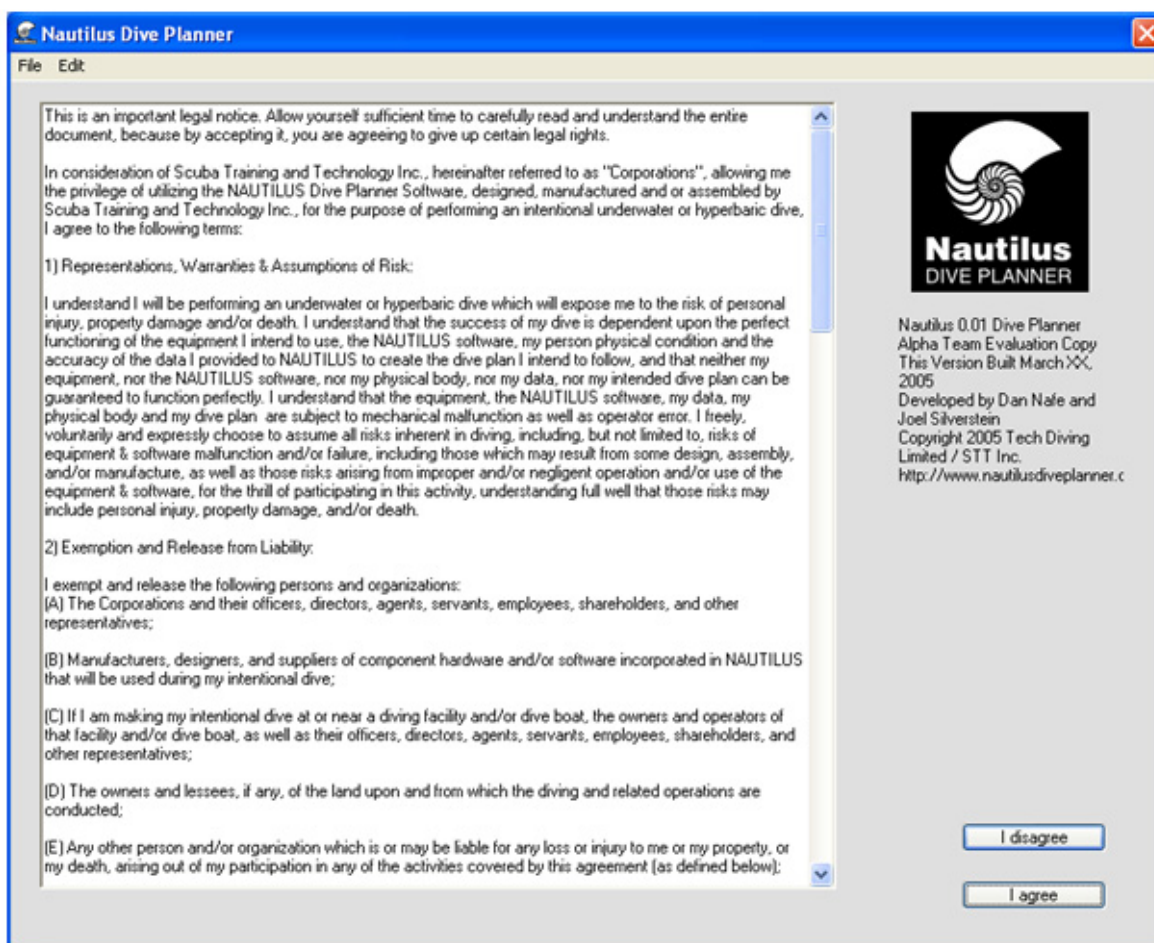
Finally a complete decompression planning program that will run on Windows, Macintosh, or Linux operating systems. Only Nautilus Dive Planner brings you all the features and algorithms in one place!



2

Nautilus Dive Planner Screen Descriptions

2.1 Opening Screen

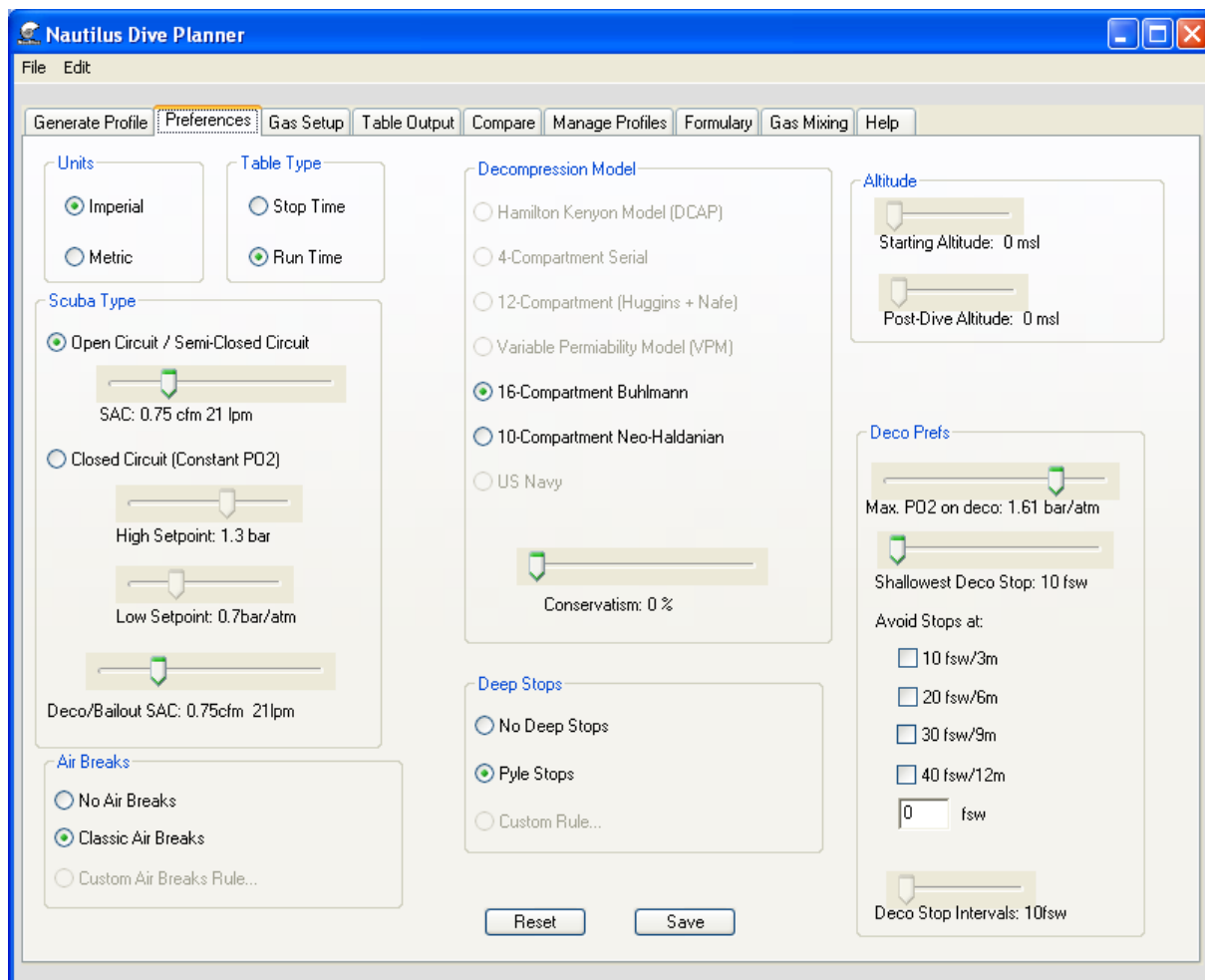


OPENING SCREEN

The opening screen of NAUTILUS Dive Planner requires the user to read and either AGREE or DISAGREE with the terms and conditions of the use of the program. Nautilus keeps track of each time the program is launched.

When the user clicks the I AGREE, button then the program will allow full features and functions. Should the user click I DISAGREE, the program will exit.

2.2 Preferences



Units: Imperial or Metric (in sea water)

Table Type: Stop Time or Run Time

Scuba Type: Open or Closed Circuit and the associated SAC rates for those modes. If Closed Circuit mode is used, the Setpoint is to be indicated here.

Air Breaks: Nautilus allows the user to have “classic” air breaks while breathing oxygen. When the decompression time on with a PO₂ of 1.3 exceeds 20 minutes, a 5 minute break will be inserted, with the next lowest nitrogen based mixture or trimixture, if nitrox is not available. Nautilus takes into consideration the time off the oxygen when calculating the remaining decompression.

Decompression Model: Choose from seven models. Keep in mind that only one model may be used for a series of dives. Switching between models during a repetitive dive series is not permitted. They include:

- Hamilton-Kenyon Model (DCAP) 11 compartment
- Buhlmann 16 compartment
- 4-Compartment Serial
- 10 Compartment Neo-Haldanian
- 12-Compartment (Huggins-Nafe)
- Variable Permeability Model (VPM)
- US Navy

Conservatism Slider: increase decompression time over the base algorithm from 0-90

Deep Stops: Choose from No-Deep Stops, “Pyle Stops,” or Custom Rule Stops. Pyle Stops inserts a 2 minute stop 1/2 way between the maximum depth of the dive and the first required stop. Then, 1/2 way again between that stop and the required stop and then 1/2 way again until the required stop is reached. NAUTILUS credits at the shallow stops when it can for these deep stops.

Altitude: Set the Starting Altitude of the dive in msl (mean sea level) and set the Post-Dive altitude. Starting Altitude is where the dive will be conducted from. Post Dive Altitude is where the diver will ascend to, after the dive is completed. This can be used where there is a mountain range the diver must cross after the dive or a non-pressurized cabin plane.

Deco Prefs:

Max PO2 on deco: Set the maximum PO2 desired for the MOD of the decompression gases to be used. Note that if 1.6 atm PO2 is desired the slider must be set at 1.61 atm PO2, otherwise, the gas will not be enabled at the 1.6 atm level. This applies to other levels as well. For 1.4 atm PO2 set it at 1.41.

Shallowest Deco Stop: Set the shallowest stop desired using the slider. Nautilus will calculate the decompression to that depth.

Avoid Stops at: This is a great option to help avoid stops in areas where it may not be feasible to do a stop due to sea conditions or topographical conditions. Chose from 4 preset depths or enter a specific depth.

Deco Stop Intervals: Set the interval between stops. (3, 5, 10, 15 fsw.) Smaller intervals make a smoother decompression shape.

SAVE: This button will save the preferences set until they are reset by the user. Upon opening NAUTILUS these preferences are enabled and table generation can begin.

RESET: Press this button to reset all the preferences to the standard defaults.

2.2.1 NAUTILUS STANDARD DEFAULTS are:

Imperial (FSW)

Stop Time

Open Circuit SAC .75 cu ft

Classic Air Breaks

16-Compartment Buhlman

15 Conservatism

No Deep Stop

Sea Level

1.61 atm PO2 for Decompression Gas

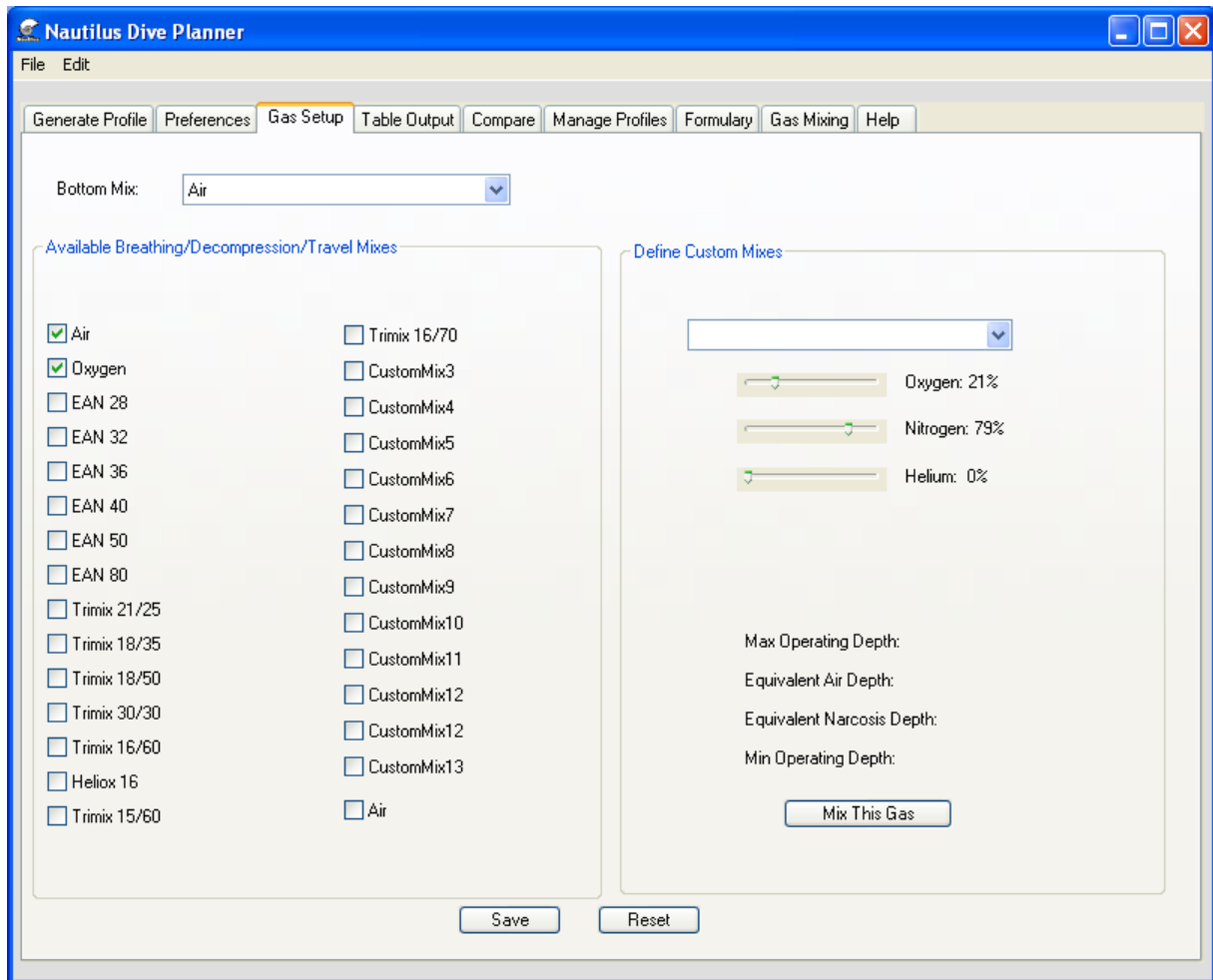
Shallowest stop at 10 fsw

NAUTILUS assumes instantaneous descent. Meaning that bottom time is calculated at the maximum depth immediatley from the time the diver leaves the surface.

Users are to follow the ascent rate indicators of their bottom timing devices or dive computers. The ascent rate to the first stop should be at a rate of 60 fsw / min (20 msw/Min.) Thereafter, 30 fsw / min (10msw/min).



2.3 Gas Setup



NAUTILUS **Gas Setup** screen is where the user creates the “Gas Portfolio” that will be available for creating profiles and tables.

Here the user will select the gases that are expected to be used for a particular dive or that the user would like to have available while planning dives.

There are 15 pre-defined gas mixtures that are commonly used for divers. There are also 14 additional “Custom Mix” placeholders available for creating additional mixes for the gas portfolio.

Creating a Custom Mix is as simple as using the sliders to specify the composition of the gas mixture desired NAUTILUS will display:

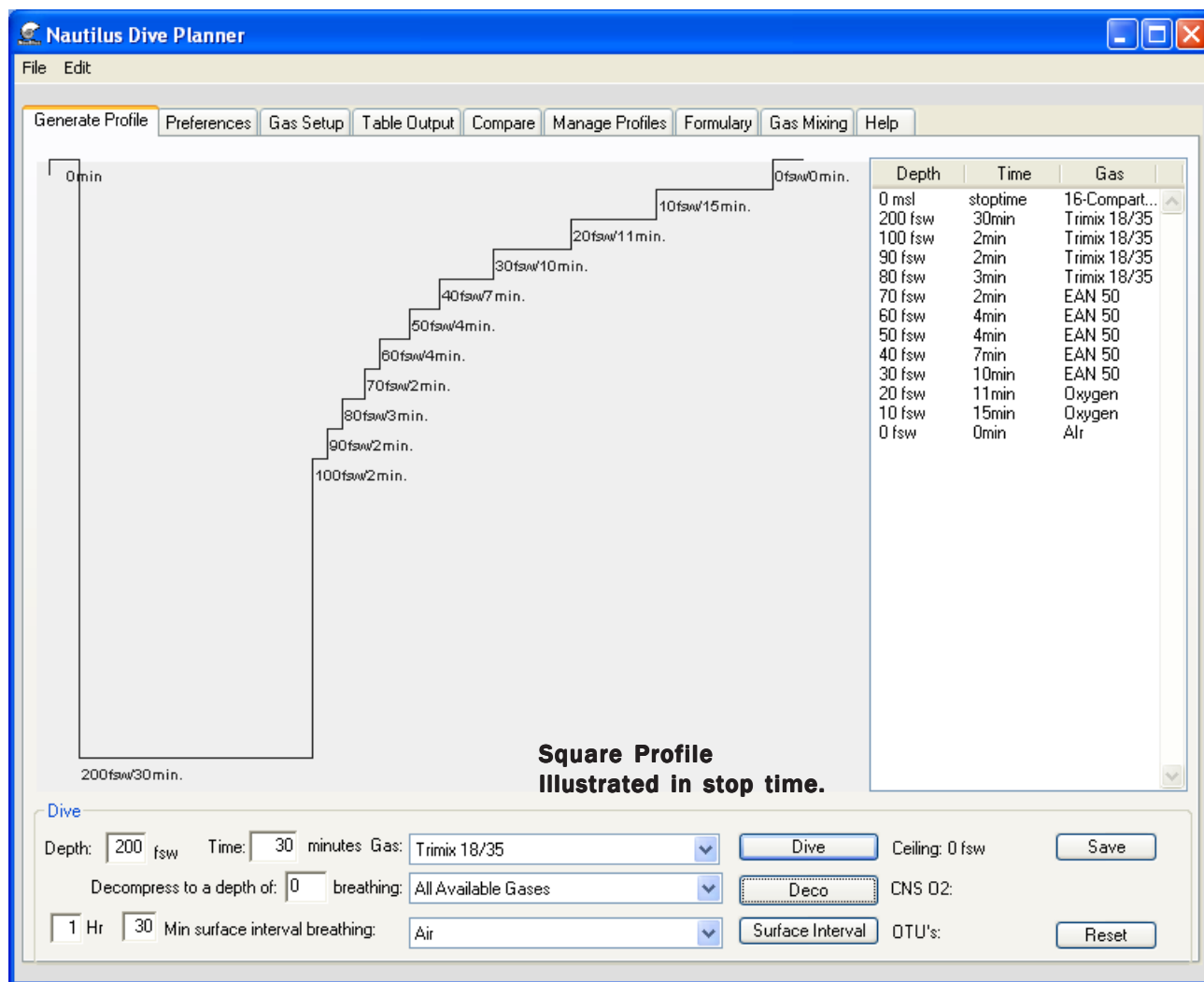
- MOD based on 1.6 atm PO₂
- Min Operating Depth assuming a PO₂ of .16 atm. - -
- Equivalent Air Depth for nitrox mixes.
- Equivalent Narcotic Depth assuming oxygen is included in the narcotic properties.

Click: Mix this Gas and it will save it to the gas portfolio.

SAVE: This button will save the gas portfolio selected and they will now be available for generating profiles.

RESET: Press this button to reset the gases in the portfolio to Air and Oxygen only.

2.4 Generate Profile



Generate Profile is the area where the user will plan the dive and generate the first set of decompression numbers.

If this is the first time using NAUTILUS the Preferences and Gas Set-up need to have been visited before generating a profile. If, however, the Preferences and Gas Setup have been completed the user can start off at the Generate Profile tab.

**Examples shown with 18/50 trimix
EAN 36% deco and 100% oxygen**

2.4.1 CREATE SINGLE SQUARE PROFILE DIVE

Generating a profile with NAUTILUS is quite simple. With the Preferences and Gas Set up already in place enter the DEPTH of the Dive and the TIME for the dive. Check the pull-down menu and ensure the bottom mix desired is selected.

Press the DIVE button. This will now enter the first “leg” of the dive. The decompression “ceiling” will be displayed to the right of the dive button. This ceiling is essentially the first stop.

To perform the decompression calculations using All Available Gases that have been selected in the GAS SET UP, confirm that there is a 0 in the “Decompress to a Depth:” area and press DECO.

NAUTILUS will calculate decompression and perform gas shifts are the appropriate levels based on the maximum PO₂ selected in the PREFERENCES tab. A general Depth / Time schedule will appear to the right of the dive graph.

From here, the user can either SAVE the dive profile by pressing the SAVE button or press RESET and start all over again.

2.4.2 CREATE A MULTILEVEL PROFILE DIVE

Creating a Multi Level Profile with NAUTILUS takes just a little more work but is still quite simple.

1. Decide the levels desired.

2. Enter the First Level in the Depth / Time boxes and press DIVE

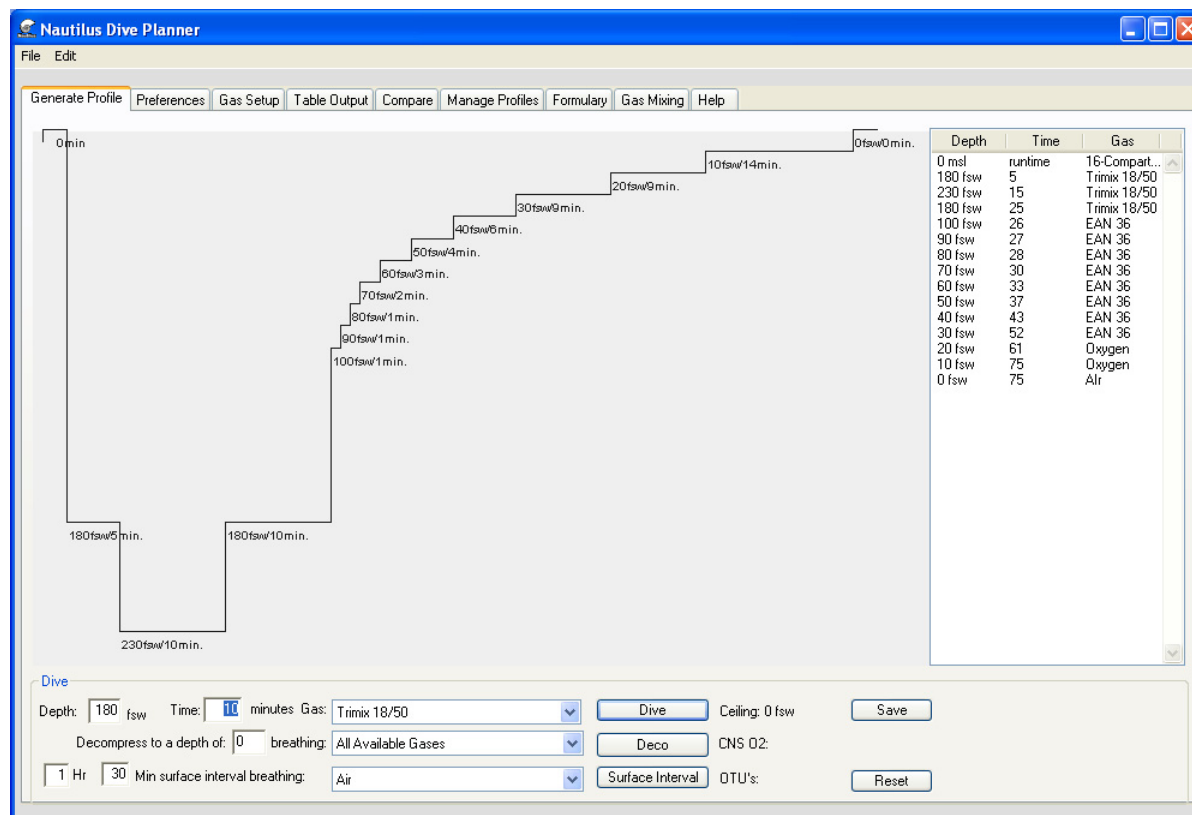
3. Enter the Second Level in the Depth / Time boxes and press DIVE

4. Enter the Third Level in the Depth / Time boxes and press DIVE

As many levels as desired may be entered. They can start out with operational descent stops or they can map out the contour of a deep wreck or cave site. The possibilities are endless!

After the final leg of the dive is entered move to the Decompress section. Look at the Ceiling next to the final DIVE button. This will be the first stop area.

PRESS the DECO button and the decompression is calculated.



CREATING PROFILES USING CLOSED CIRCUIT

To create dive profiles where the diver will be using a closed circuit rebreather, the user needs to:

1. Enter the **Preferences Tab** and change the Scuba Type from Open Circuit to Closed Circuit.
2. Set the **High Set Point and Low Set Point** for the rebreather you are using.

NAUTILUS ALPHA VERSION assumes binary diluent gases for the calculations when using a CCR. Meaning, if you are using Heliox, it assumes you will be using only helium and oxygen and that your unit will adjust the oxygen accordingly with the balance being helium. If you are using nitrox, then the unit will adjust for the oxygen accordingly with the balance being nitrogen.



Most CCR divers will have the diluent for helium dives set up as a 17/83 oxygen/ helium mixture and will have oxygen on board. For nitrox dives they will have air 21/ 79 oxygen/nitrogen as the diluent and will have oxygen on board as well.

NAUTILUS does not presently calculate CCR decompression using trimixture diluents.

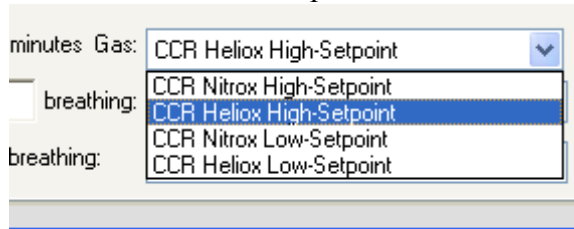
3. SAC for the “Deco / Bail Out” should off-board OC gasses be desired.
4. Continue to set the other preferences.
5. Press SAVE -- the preferences are now saved.

Next enter the Gas Setup Tab

Under the Gas Setup Tab, the CCR user can deselect all gas mixtures OR can select a bailout gas or off-board decompression gasses. When gases are either selected or deselected press SAVE and the gas portfolio will be saved.

ENTER THE CCR PROFILE

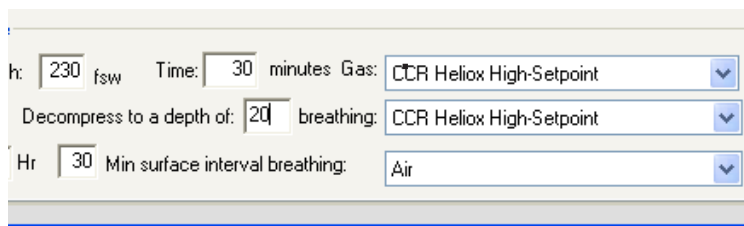
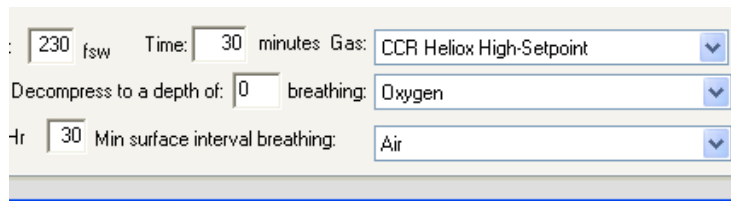
Select the **Generate Profile** tab. Enter the Depth and Time and select the Setpoint gas in the pull-down to the right of the minutes box then press DIVE.



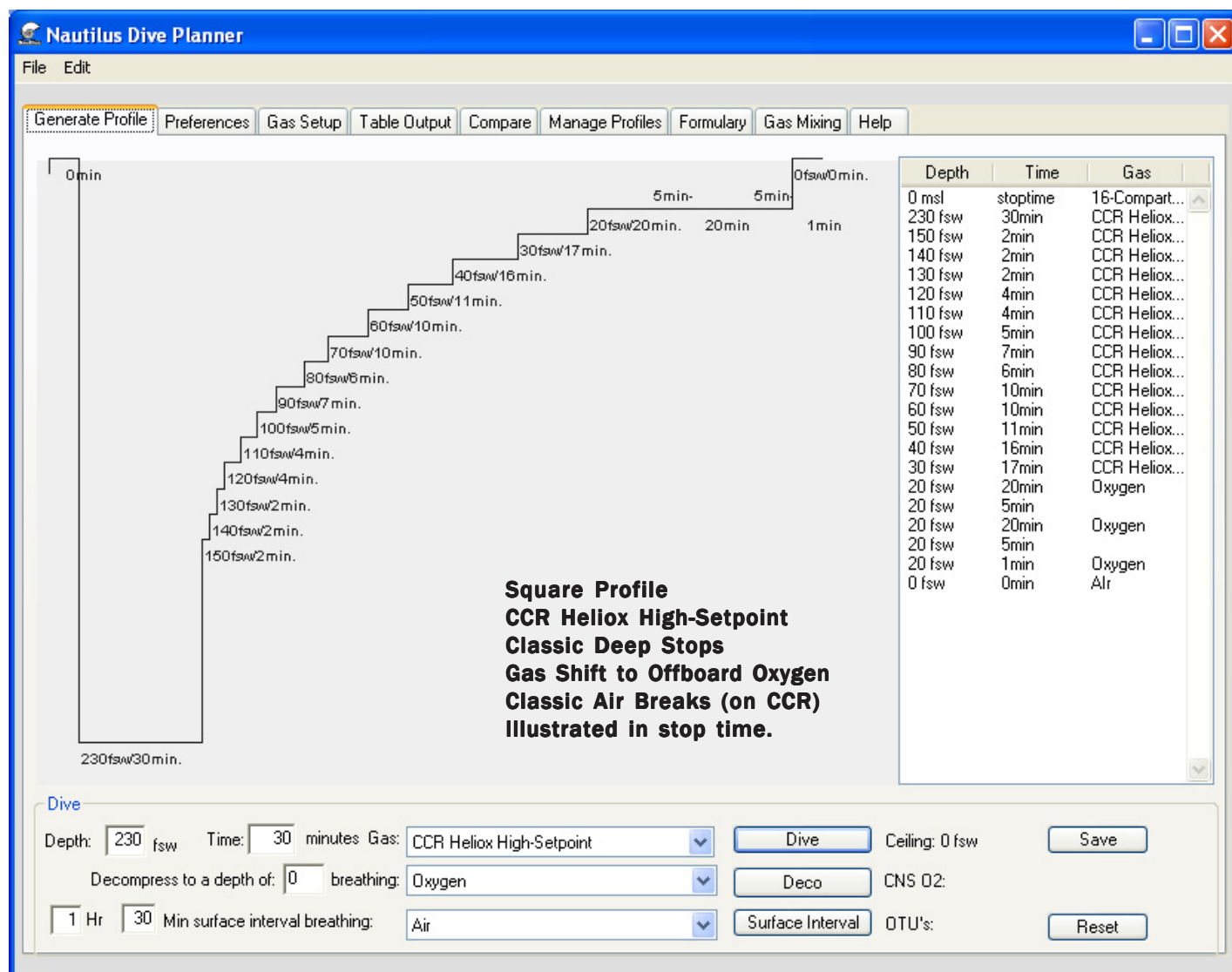
After the dive has completed the first leg the user can decide on how the decompression will be completed by selecting the appropriate decompression gases and /or a setpoint.

If the decompression will be with all CCR then the user need only select that set point gas and press DECO. The decompression will now be completed.

If an off-board decompression gas will be used, tell NAUTILUS to decompress to the desired depth or the MOD of the off-board decompression gas using the CCR set point, then select the off-board decompression gas for completion of the decompression. (eg: decompress to habitat depth, then complete decompression with OC gas.)

NAUTILUS will then calculate the decompression accordingly with the gas shift. If air breaks were selected, then it will calculate those as well.



NAUTILUS will allow the use of multiple off-board decompression gases and allow the user to create “what if” scenarios, illustrating bail outs with off-board gases as well. The user needs to set up a gas portfolio under the GAS SETUP tab to have access to those gases.

Another feature of NAUTILUS is its ability to allow the user to conduct repetitive dives (next section) moving from CCR to OC seamlessly. It is not uncommon for the dive professional to conduct one dive using CCR and then complete another dive with OC scuba. NAUTILUS will help the user create these special schedules. All the user needs to do is to create the gas portfolio for BOTH dives in the initial setup.

Creating multi level dives with CCR is no different than when they are created with OC modes of diving. Simply select each level desired and press the DIVE button until the dive is completed then press DECO with the desired decompression Setpoint or off board gases as discussed earlier.

In the classic book *20,000 Leagues Under the Sea*. Captain Nemo’s “Nautilus” submarine had a library that held more than 12,000 books.

2.4.4 REPETITIVE DIVES

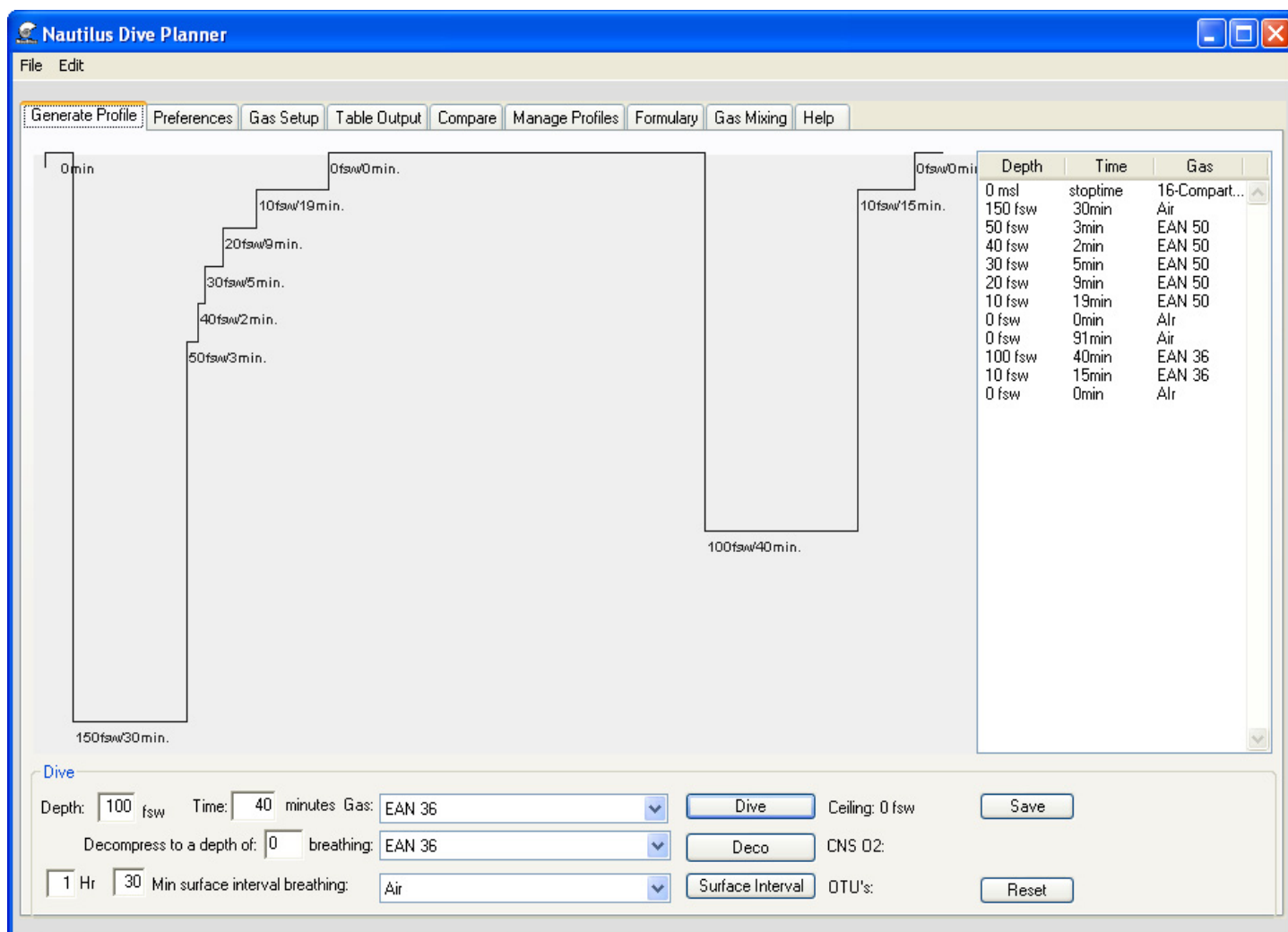
NAUTILUS creates repetitive dives with relative ease. After the user has set up Preferences and Gas Setup, return to the Generate Profile tab.

Create the first dive as described earlier indicating depth and time and the bottom gas to be used. Then, complete the decompression. After the decompression is complete, enter the SURFACE interval in Hours and Minutes. For purposes of this illustration, select AIR as the surface interval gas.

After the Surface Interval is entered, press the SURFACE INTERVAL button and the surface interval will be created.

Next, enter the new dive with the new gas mixes (if changed) and complete the dive as normal. If a third dive is desired or a series of dives is desired, repeat the repetitive dive process.

Note: NAUTILUS will allow for Surface intervals using gases other than AIR, but must only be done with proper supervision and support.



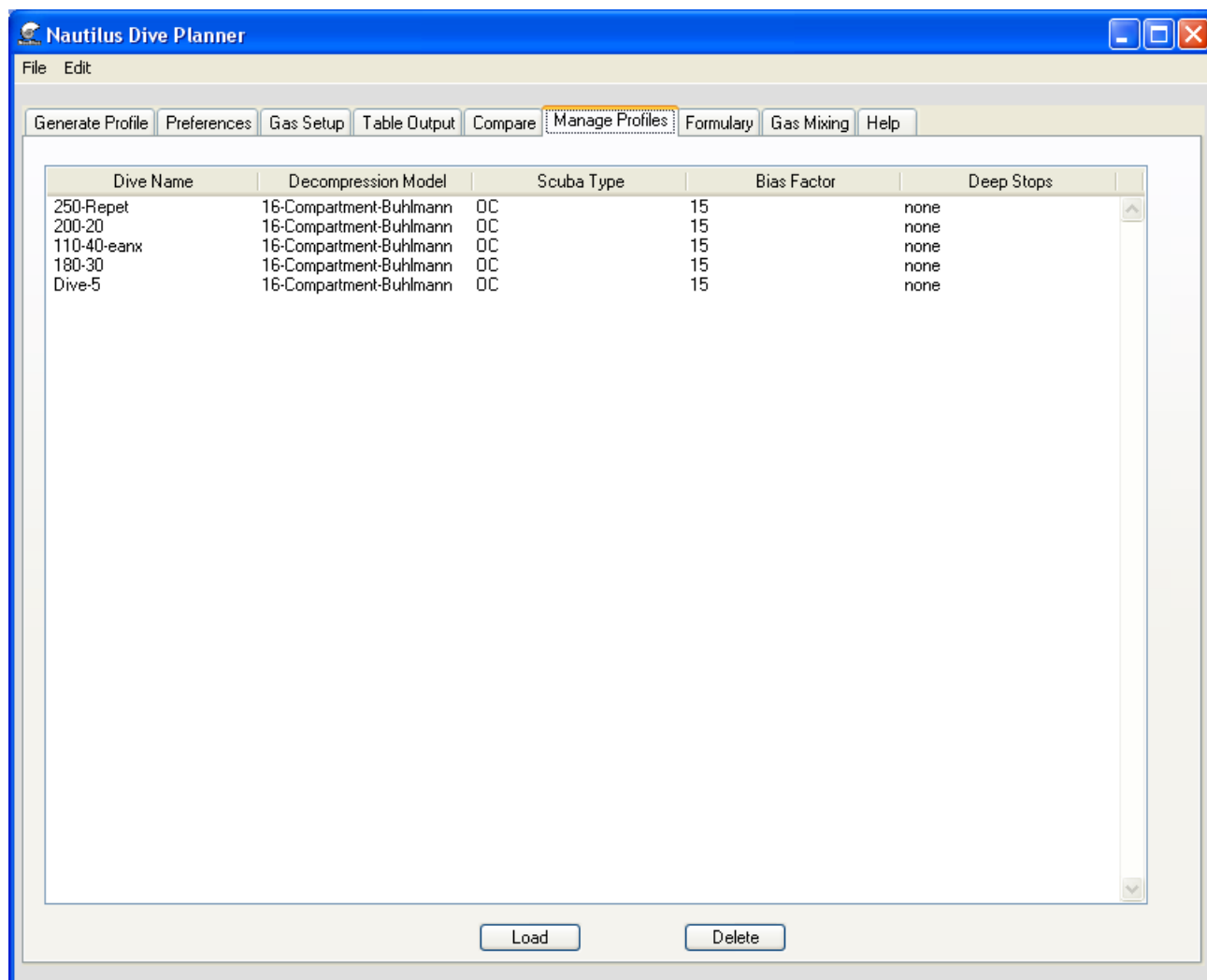
2.5 Manage Profiles

NAUTILUS has a dive filing system that allows the user to SAVE each and every dive profile for future use. Each profile saved includes the actual profile, gas selections, and preferences.

To save a profile press the SAVE button on the **Generate Profile** tab. If a specific file name is desired, enter it, otherwise NAUTILUS will assign a “Dive-XX” number to the saved data.

To load a dive, enter the **Manage Profile** tab, select a particular dive, and press LOAD. The dive will be loaded back into the Generate Profile tab where it can be viewed or modified.

To delete a dive, enter the Manage Profile tab, select a particular dive and press DELETE. The dive will be deleted from the NAUTILUS database.



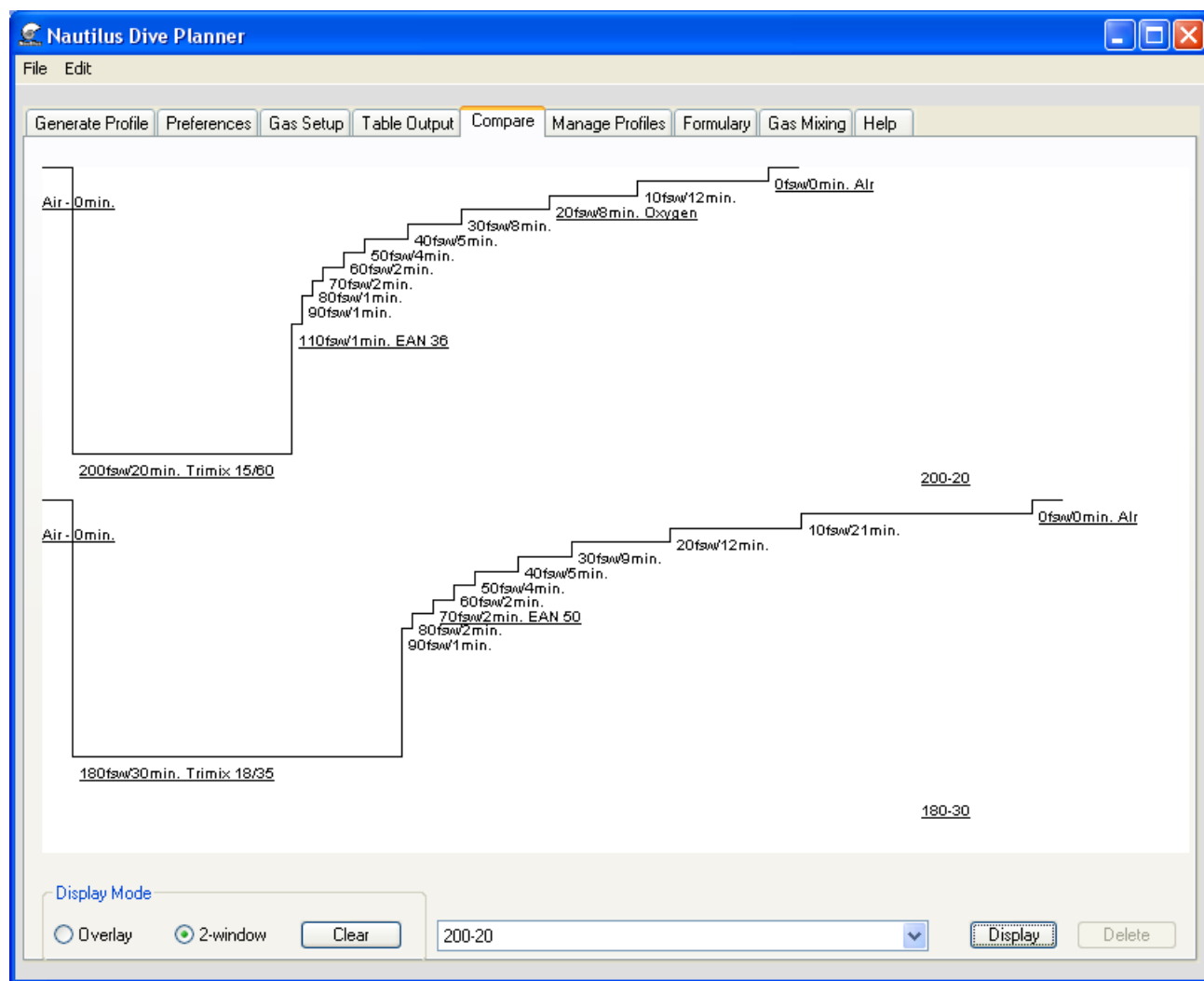
2.6 Compare

NAUTILUS features a unique COMPARE function screen that allows the user to select two dive profiles and compare them in two graphical forms.

Overlay: In this mode, NAUTILUS will overlay two dive profiles. This view is helpful in visualizing the effects of time and depth of two dives on the decompression of each. This is helpful in identifying operational problems with a particular dive profile.

Two-Window: In this mode, NAUTILUS will place the dive profiles in two separate windows on the screen. This mode allows a more general comparison of dissimilar dive profiles. It is helpful in analyzing multi-level dives and in comparing dives using either Open Circuit or Closed Circuit equipment.

To access the dives, use the pull-down Menu and press **DISPLAY** for each dive desired. NAUTILUS works best with two dives. More windows will be available in future versions of NAUTILUS.



2.7 Table Output

NAUTILUS allows the user to output the generated dive profile in a variety of formats. These formats are generally referred to as Tables or Schedules.

A Table is defined as a Schedule for a Single dive. NAUTILUS allows for a variety of table “formats.” In the Alpha Version there are four Table Formats available.

Classic - This format follows that of the traditional US Navy type tables.

Enhanced - This format will show a single depth dive and bottom time with one or two time intervals. A Detailed table will show, The Model Name, Table Title (saved name) Bottom Mix, Decompression mixes, gas shift depths, decompression times, oxygen partial pressures, and oxygen limits achieved in both CNS % and OTU, as well as any operational instructions.

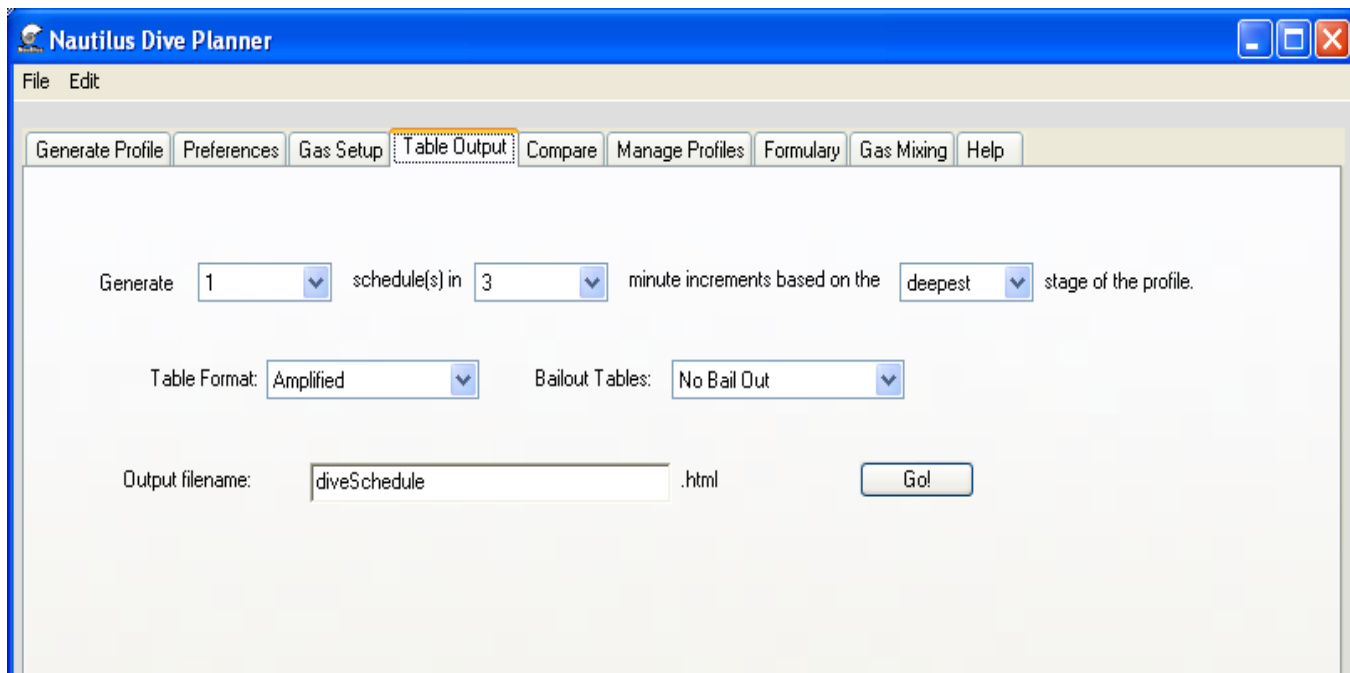
Condensed - This format will show a single depth with a series of bottom times in 3 or 5 minute intervals.

Speed - This format is a compact format for printing on small cards and laminating to be carried by the diver. Users are strongly urged to print Amplified tables to review all the pertinent data about the dive before using Speed Tables.

The series of schedules can be generated with EITHER the deepest portion of the dive or the longest portion of the dive. This is helpful for multi level dives where bailout schedules are desired.

The user can also generate “what-if” tables to take into account lost decompression gases.

NAUTILUS outputs to HTML files now which can be viewed in the standard web browser and printed in whatever mode is preferred.



The screenshot shows the Nautilus Dive Planner application window. The title bar reads "Nautilus Dive Planner". Below the title bar is a menu bar with "File" and "Edit". A toolbar contains buttons for "Generate Profile", "Preferences", "Gas Setup", "Table Output" (which is highlighted with a dashed border), "Compare", "Manage Profiles", "Formulary", "Gas Mixing", and "Help". The main area of the window contains the following controls:

- Generate schedule(s) in minute increments based on the stage of the profile.
- Table Format:
- Bailout Tables:
- Output filename: .html
-



VERSION 1.0

2.8 Formulary

2.9 Gas Mixing

2.10 Help

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completed at this time.**

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3

Nautilus Dive Planner Decompression Models

3.1 NAUTILUS DIVE PLANNER DECOMPRESSION MODELS

The Nautilus Dive Planner provides an interface into the following decompression algorithms:

Parallel models:

Hamilton-Kenyon 11 Compartment Parallel (TII-11F6)

Buhlmann 16 Compartment Parallel (ZHL-16a)

Hamilton-Kenyon Bubble Model

Buhlman Bubble Model (VPM-X)

US Navy 1965 (12-Compartment Parallel)

3.2 Parallel Model Overview

These models simultaneously load all of the theoretical compartments with inert gas at an exponential rate based upon each compartment's half-time. All models use a value for each compartment that determines its supersaturation gradient. The Buhlmann model uses two factors ("a" and "b") and the other models use a value called "M". The compartment that has the "deepest" minimum tolerable ambient pressure is said to be the "controlling" compartment, based upon the compartments inert gas load factored against its allowable amount of supersaturation ("a" and "b", or "M"). Theoretically, as long as the diver does not ascend above the minimum allowable depth, no clinically observable decompression illness symptoms are likely to be observed.

The Buhlmann models are "folded" into many popular dive

computers that are made in Europe. (Interestingly, these machines only track eight (8) compartments, therefore a NAUTILUS derived repetitive dive profile will be more conservative than a dive computer using what is billed to be the "Buhlmann" model!) Buhlmann models track helium loading and allow for the tracking of helium + nitrogen loading in the theoretical compartments. These methods were first used in manned dives in the early and mid 1960's.

The 10 Compartment Parallel, 12-Compartment model and US Navy model are based on the calculation methods derived by the Haldane's dating back to the early 1900's. The 10 Compartment model is used in many US made dive computers and the 12 Compartment model was used in the Orca Edge Dive computer. In 1989, Nafe was able to extend Huggins 12-Compartment model to track using the same computational method that Buhlmann had been using for the previous 25+ years. Nautilus allows the tracking of helium in the diver's breathing mixture using this computational method, which is similar to using "equivalent air depth" for employing an air table while breathing nitrox.



No diving profile or decompression model including those generated from within NAUTILUS can assure me that I will not be injured or killed.

3.3 Hamilton-Kenyon Model

11 Compartment Parallel (TIIa-11F6) (aka DCAP)

NAUTILUS Dive Planner is the only commercially available decompression software product to license the Hamilton-Kenyon decompression model for use in generating decompression schedules for the technical diver.

The “model” has been incorporated into some proprietary rebreather decompression computers, most notably the Cis Lunar and others to be available shortly. Some of Dr. Hamilton’s algorithms for oxygen handling have been used in many of the popular dive computers. Until now the only way to get “tables” using the Hamilton-Kenyon Model was to have access to the famed Key West Consortium Tables which were the basis for most of the trimix diving done during the 1990s, or to have tables provided by NOAA during the USS Monitor projects (NOAA Trimix 18/50 is based on Hamilton-Kenyon Model) or to have a set of tables created on a custom basis by Hamilton Research Ltd. Dr. Hamilton has created highly reliable tables using the TII-11F6 model for such notable dive operations as: Key West Consortium, Casadore Project, Pillar Project, WKPP, Andrea Doria Expeditions, USS Monitor Expeditions and many others.

NAUTILUS is fortunate to have been able to license the Hamilton-Kenyon Model for the NAUTILUS Dive Planner Software. The relationship between R.W. Bill Hamilton and NAUTILUS co-author Joel Silverstein goes back more than a decade. The two have worked on many projects together including authoring two texts on oxygen enriched air diving for NAUI and for the YMCA. They were co-authors of the NOAA Diving Manual sections on Nitrox and Mixed Gas Diving and were the principal and co-investigators for the Decompression Survey of Air and Air with Oxygen diving for the US Navy Biomedical Research division. Mr. Silverstein has relied on the Hamilton-Kenyon Model for his personal diving and that of his projects since 1991.

The Hamilton-Kenyon Model has been referred to over the years as the DCAP model. DCAP is not a model it is a computer analysis program that allows Dr. Hamilton to create

and model decompression profiles that extend far beyond the uses and needs of the technical diver.

The computational program identified as the Hamilton-Kenyon algorithm uses, in our internal terminology, the Tonawanda Ila model using Matrix MF11F6 computed with Hamilton Research’s DCAP. It uses a Neo-Haldanian computational algorithm designated Haldane-Workman-Schreiner. It uses 11 halftime compartments ranging from 5 to 670 min. The ascent-limiting matrix was developed to permit deep air dives using air decompression without compromising established decompressions from short, shallow air dives. The development was empirical, based heavily on experience, but formal statistics were not used to design the matrix. Although designed originally for air the algorithm has proven to be highly reliable for dives using oxygen-nitrogen-helium trimixes.

DCAP dates back to commercial diving in the 1960’s when the search for offshore oil found commercial diving companies doing heliox diving; up to that time only Navy tables were available, and they did not meet all needs for offshore diving. Dr. Heinz Schreiner led a development team at Ocean Systems, Inc., in both computation and laboratory validation of new heliox tables. This was done in collaboration with others, some of whom were then the leaders in decompression, including Bob Workman, Chris Lambertsen, Val Hempleman, and Albert Bühlmann. Schreiner’s computational methods were based on Haldane’s concepts, and they relied heavily on feedback from the field and other empirical information.

Following corporate changes at Ocean Systems, Inc. the task was picked up by Dave Kenyon and Dr. Bill Hamilton and they offered decompression services to others in the field. From this, in about 1975 the need for a number of different tables by a European client led to the idea for Hamilton Research, Ltd., to provide a program to generate decompression tables instead of just providing the tables themselves. That is, to sell the goose instead of just the

eggs. The idea was to design a program that could be used by engineers and diving supervisors as well as researchers and would not need a programmer as such. This concept was accepted, and DCAP was developed and acquired by several major diving research laboratories. A project to develop deep air tables by one of the DCAP users, the Swedish Navy, led to a highly reliable matrix that later was found to work well for trimix diving also. DCAP is the acronym for Decompression Computational Analysis Program.

Description of the DCAP program.

Thus DCAP itself is more a tool for generating and analyzing tables and profiles than it is a specific model. The User enters a page of instructions, a Basecase file, into a PC running DCAP. This describes the dive or dives to be done and gas mixes, profiles, detailed instructions to the diver, etc. The Basecase also references other files which define other variables such as units, the computational model, a matrix of ascent limits or M-values, the format for the table or tables, and names other output files to be generated such as graphics or gas loadings; a notebook file can keep a record of what has been done. These files use diving and not computer terminology, normally English, but can be translated into other languages by the user.

A number of models or algorithms are used by decompression developers, and they are still evolving; some are better than others. All of them that work rely heavily on empirical experience. Hamilton-Kenyon's experience is greatest with the neo-Haldanian Haldane-Workman-Schreiner model designated Tonawanda Ila. incorporated in to NAUTILUS as the **Hamilton-Kenyon Model**.

Haldane's concept was that different parts of the body (compartments), take up gas at different rates, and this is limited by perfusion, the blood's ability to carry gas from the lungs to and from the tissues (rather than by diffusion around a capillary). Uptake and elimination between lung and tissue follows exponential mathematics, which means simply that the rate of transfer is proportional to the

difference; these rates are defined by half times for each compartment (often called tissues but they are not anatomical), the time it takes for half the difference to be equilibrated (half the remaining difference takes another half time, and so on). Gas loadings of inert gases are measured in partial pressures. The original Haldane method provided ascent constraints as limiting ratios of partial pressures (the ratio of current depth to target depth). Because this worked best only for short, shallow air dives, Workman based ascent constraints on differential pressures. A matrix of maximum tolerable gas loadings (M-values) for each compartment at each depth defined the ascent limits; the gas loading calculated for each compartment is compared with the limit at each depth, and ascent to the next stop is allowed when the loadings in all compartments are less than the M-values (the loadings decay exponentially as ambient pressure is reduced and gases leave the body). Schreiner made this work efficiently for different inert gases by using different half times for each inert gas and summing the loadings in each compartment. Haldane used 6 half times, others use more, Hamilton-Kenyon use 11 half times.

Since many decompression computations are done with Bühlmann's published method, it is relevant to compare it with Tonawanda Ila. Bühlmann uses a similar approach, except that instead of a matrix of M-values it uses factors a and b for each of the half times; these tolerated pressures can be converted algebraically to M-values. In the faster compartments (shorter half times) the inert gases are summed and compared with a calculated limit, and in longer compartments the different inert gases have different a and b values; these are divided proportionally according to the proportion of each inert gas in the mix.

Both methods can vary in their conservatism, but in present practice the Tonawanda Ila model using the matrix described, identified as MM11F6, (Hamilton-Kenyon) is a bit more conservative than the unmodified Bühlmann method. This combination has worked well with trimix dives. The most popular use of the MM11F6 matrix has been for the well known "Key West Consortium Trimix Diving Tables, the

NOAA Trimix Diving Tables, and the Andrea Doria Off-Shore Diving Tables. These tables have thousands of dives experience with very good results.. This is the model included in NAUTILUS.

‘Thus to wrap up, DCAP is a practical result of many years of collective experience in preparing and evaluating many types of decompression tables. The DCAP concept does not limit it to calculations with any specific model there is currently a choice of several models, and others are under development. DCAP’s main feature is that it facilitates the computational and table production process. It can allow different models, approaches, ascent constraints, and table configurations to be used. A good set of criteria provides a practical approach to trimix decompression in the self-contained, open circuit range with a good track record.

While it would be wonderful for DCAP to be an inexpensive desktop decompression program it just can’t. The powerful features of DCAP make it far too complicated and involves far too many variables that need to be handled by a researcher to make it practical for recreational use. This is where NAUTILUS comes in. NAUTILUS allows the free swimming diver the ability to create dive excursion profiles with reasonable assurance that the numbers work well. NAUTILUS incorporates the Hamilton-Kenyon Algorithm derived from Tonawanda Iia.

3.5 Hamilton Kenyon Bubble Model (HKBM)

The Hamilton-Kenyon Bubble Model (HKBM) is a melding of Haldane’s method of calculating inert gas uptake into theoretical compartments. Keller’s method of summing the partial pressures of multiple inert gas uptake is employed as well. In the Hamilton-Kenyon Bubble Model, the half-times for each compartment are taken from the Hamilton-Kenyon decompression model that has years of reliable decompression schedule production.

1. Rather than using Workman’s M-value methodology for determining allowable supersaturation for the theoretical compartments, Yount’s “tiny-bubble”

method of calculating allowable compartment supersaturation is employed.

Application of Yount’s method to Hamilton-Kenyon’s gas uptake model produces decompression schedules that have initial decompression stops up to twice as deep as conventional dissolved gas models and shallow decompression stop times that are significantly shorter than dissolved gas models call for. The use of Hamilton and Kenyon’s compartment half times avoids the extremely aggressive shallow decompression stop times that VPM and RGBM models yield.

This combination of Hamilton, Kenyon, and Yount produce decompression schedules that algorithmically call for deep stops, rather than arbitrarily adding them into a dissolved gas model and having to “pay for it” at the shallow end of the schedule. The shallow stops are not arbitrarily shortened based upon the intuition of diver’s in the field.

The schedules produced by the Hamilton-Kenyon Bubble Model square with the past 15 years of technical diving experience that has yielded the following observations:

- Dissolved gas models do not produce initial stops at great enough depth
- Shallow stops called for by dissolved gas models are much longer than necessary
- Deep stops arbitrarily added to dissolved gas model add an unwarranted shallow decompression penalty, as do adjustments to the M-values
- Buhlman’s halftimes used with dual-phase bubble models (VPM) may be slightly too aggressive for field use (skin-bends are commonly encountered)

Hamilton-Kenyon Bubble Model produces schedules that include stops and times that describe a more linear, rather than exponential arc across the depth time matrix, yet still take into account the empirically derived compartment halftimes.

3.6 Variable Permeability Model (VPM)

Dr. David Yount created the Variable Permeability Model that takes into account the suspicion that sub-clinical bubbling occurs on every dive of significant depth and/or time. The VPM-A, VPM-B, VPM-E and RGBM models were derived from this work initially done by Yount and are very popular with technical divers today.

The following is an excerpt from Eric Maiken who has done a significant amount of work with VPM

The Varying Permeability Model (VPM) was developed to model laboratory observations of bubble formation and growth in both inanimate (never been alive) and in vivo (soon dead) systems exposed to pressure. In 1986, this model was applied by researchers at the University of Hawaii to calculate Diving Decompression Tables (Reference 1). Although the original VPM is considered dated by specialists in hyperbaric medicine, the time lag between the formulation and public release of the latest decompression methods has left many divers following ascent schedules that are justified by obsolete Victorian era physical models. Further compounding the problem is the widespread use of commercial decompression software with excessive arbitrary parameters hiding behind siren-song front-ends that allow programmers to dish out crucial physiological advice. Finally, the mathematical and physical bases of the bubble models have kept them inaccessible to all without degrees in physics or math and so, apart from reports filtering back from the front lines, few have understood, seen or used this stuff. So, caveat emptor—and beware too!

The VPM presumes that microscopic voids, cavities, nuclei exist in water, and tissues that contain water before the start of a dive. Any nuclei larger than a specific “critical” size, which is related to the maximum dive depth (exposure pressure), will grow upon decompression. The VPM aims to minimize the total volume of these growing bubbles by keeping the external pressure large, and the inspired inert gas partial pressures low during decompression.

It is important to note that the total decompression times generated by the simplified VPM were *FORCED* to be similar to the US NAVY Standard/Exceptional Air deco times. However, much of the decompression time is deeper than the USN depths. Presumably, a diver would evolve fewer bubbles using a VPM schedule than on the Navy table. This is not very stringent once you consider the risky (O₂ & bends) nature of the old USN exceptional exposure tables. Yount and Hoffman might better have forced the times to look like Bühlmann’s for conservatism. The parameters in the open source code produce Bühlmann-like no-stop times, and total decompression times between the old USN tables and the Bühlmann tables.

Why are VPM Decompression Tables so Similar to the RGBM Tables?

Why have VPM tables always been so similar to Bruce Wienke’s RGBM tables? Until 2002, this was simply because the RGBM was essentially the same as the VPM for a single decompression dive. Even though Wienke claims to have “abandoned” VPM, his publications and publicity from vendor partners believe this as marketing over substance. Wienke apparently still uses core elements of Yount and Hoffman’s VPM algorithm as a basis for the RGBM. Even today, in 2004, it can be demonstrated from commercial programs that the “full-up” RGBM is still underpinned by Yount and Hoffman’s iterative algorithm. With the wide distribution of open source VPM, Wienke was placed under pressure to differentiate his product by customers who had paid for material that could be obtained virtually for free. Since 2002, this has resulted in a new RGBM model, publicized in dive industry print and venues. Nonetheless, as demonstrated by the close correlation of ascent data for VPM and RGBM, this work has actually only resulted in incremental adjustments of the model. You pay your money and you take your chances.

Comparison of the VPM to Conventional Decompression Procedures

A major difference between the VPM and standard supersaturation algorithms is that the VPM programs use an iterative procedure to calculate a decompression schedule. In each step of the iteration, a new decompression schedule is calculated. The total decompression time is then fed-back into the calculation to revise the critical gradients (SUB PNEW in the BASIC Programs), and a more liberal schedule is produced. Maybe this should be called the “IGBM” —the increased gradient bubble model ;*) This process of updating the ascent repeats until the decompression time converges to what supposedly corresponds to the formation of the maximal allowable amount of free gas. The first and last schedules produced for a short dive are often quite different. This results from the contribution of both the magnitude of the growth gradient +G and the time that the gradient acts to drive bubble growth. After a short dive, the tissues will off gas rapidly to circulation. Hence, because the time that the gradient acts is small, the magnitude of G can be increased by allowing shorter and shallower stops.

VPM tables handle the in and out gassing of dissolved gas in tissues the same way as conventional neo-Haldane calculations do. That is, parallel compartments with exponential half-times ranging from minutes to hours are used to model the uptake and elimination of inert gas by the body. This in and off gassing is handled symmetrically in all of my programs. The divergence of the VPM from conventional calculations is in the details of how a diver’s ascent is controlled. Rather than setting limits on the maximum pressure ratio/difference between gas dissolved in tissues and ambient pressure (supersaturation), ascents are limited by controlling the volume of gas that evolves in the body due to the inevitable formation of bubbles. As long as this volume is kept smaller than a certain “critical volume,” it is presumed that a diver’s body has the ability to tolerate the bubbles. If the volume of bubbles exceeds the critical volume, the diver is at risk of a pain-hit or worse. The volume of the gas in bubbles is related to the product: (number of bubbles) x (Gradient) x (growth time). The number of growing bubbles

is set by the maximum compression encountered on a dive. This crushing pressure is related to the deepest depth of the dive as well as the descent rate and gas mixture. All of the programs on this site directly relate pCrush to the maximum depth. The gradients and bubble growth time are controlled by the ascent schedule, with the surface explicitly considered the last decompression stop.

Rather than using tens or hundreds of arbitrary of parameters to generate ascent schedules, the main result

of the VPM is the replacement of the ascent-limiting matrix of M/a-b values with only four constants, corresponding to measurable physical and physiological quantities. In the BASIC programs, they are found in SUB DIVEDATA. The minimum bubble radius excitable into growth $r_0 = r_o$, the skin tension of bubble nuclei $\gamma = \gamma_c$, the nuclear crushing tension $\gamma_c = \gamma_c$, and the maximum tolerable volume of bubbles, which is proportional to $\lambda = \lambda$. For the hour-long time scales treated by this program, the nuclear regeneration time (see Yount’s eq. 2) is essentially infinite, and hence, not used. From these constants, critical gradients G are formed in SUB DIVEDATA on the first iteration and then in SUB PNEW on subsequent iterations. The critical gradients limit ascents because they are directly related to the rate of bubble-growth by the diffusion equation.

Reference: Eric Maiken

http://www.decompression.org/maiken/VPM_Background.htm

The appendix of: D.E. Yount, D.C. Hoffman, *On the Use of a Bubble Formation Model to Calculate Diving Tables*. Aviation, Space, and Environmental Medicine, February, 1986.

NAUTILUS incorporates the Variable Permeability Model into its portfolio of Decompression Models. The user will have control over the values used for Gamma, Lambda, and M yielding what NAUTILUS designates as VPM-x



3.6 Future Models and Integration

The goal of NAUTILUS Dive Planner is to be the single source tool for decompression planning for the advanced and technical diver. We will continue to seek out and work with the best minds in decompression modeling and bring to NAUTILUS more reliable models as time progresses.

We hope with time to incorporate some of the Navy Probability models including V-VAL and others.

We also expect to incorporate the ability to import data from the more popular dive computers and dive data recorders. This will enable users to “pull” dive profiles into NAUTILUS and use that data as the basis for creating repetitive dive schedules. But that is in the future.

**THIS MANUAL IS NOT
COMPLETE - UPDATED
VERSIONS ARE AVAILABLE ON
OUR WEBSITE AT:**

<http://www.nautilusdiveplanner.com>



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